



IRAN'S LOOMING WATER BANKRUPTCY

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“Iran’s Looming Water Bankruptcy”

Iran's Water Crisis is an Underappreciated Global Hot Spot

Iran's rapid groundwater depletion and inexorable slide toward a serious water and food security crisis is an issue of regional—and arguably, global—importance.¹ Iran's current water stress is partly a product of hydrology and climate. But perhaps most of all, it stems from decades of sanctions and compounding political mismanagement that is likely to make it very difficult to alleviate the emerging crisis before it wreaks lasting damage upon the country.

Water shortages often exacerbate existing political and social instability and heighten governments' focus on food security. This matters because Iran is a Middle East power player and key global energy supplier home to more than 80 million people, many of whom could be displaced by a worsening water supply situation. Iran's internal problems could ripple far beyond its borders, an important issue given substantial Iranian involvement in multiple regional conflicts. As such, policymakers in the Gulf region and in Washington should pay closer attention to this unfolding situation.

Is Iran “Water Bankrupt”?

Iran water expert Ali Mirchi and his colleagues have advanced an excellent conceptual lens through which to analyze the country's hydrological woes: “water bankruptcy.”² While the idea of being “bankrupt” is typically used as a legal concept, it accurately describes Iran's current state of water affairs, since water withdrawals significantly exceed the ability of aquifers, rivers, and lakes to recharge and replenish. In essence, the country is becoming water insolvent because the “liabilities” (water withdrawals) exceed the “reasonable market value of assets held” (i.e., aquifer recharge rates and replenishment of surface water bodies).³

Most pointedly, an enterprise that becomes bankrupt typically does not cease to exist. Rather, it is generally forced into significant—and often painful—restructuring as part of its reckoning with reality. Iran is increasingly caught in a hydrological and politically constructed trap, underpinned by the reality that it withdraws far more water for agriculture and other uses each year than nature can replenish. As Peter Gleick of the Pacific Institute elegantly summarizes:

“Once extraction of water exceeds natural rates of replenishment, the only long-term options are to reduce demand to sustainable levels, move the

¹ The UN Food and Agriculture Organization (FAO) estimated that as of 2004, the latest available data point, Iran's groundwater resources were being depleted at a rate of 3.8 km³ per year. This is enough water to grow a million tonnes per year of wheat in Iran. With multiple droughts in recent years and significant increases in domestic wheat cultivation, Iran's groundwater depletion rate has very likely accelerated. See “Iran,” FAO Aquastat, http://www.fao.org/nr/water/aquastat/countries_regions/irn/index.stm.

² Kaveh Madani, Amir Agha Kouchak, and Ali Mirchi, “Iran's Socio-economic Drought: Challenges of a Water-Bankrupt Nation,” *Iranian Studies* 49(2016): 997-1016.

³ Definitions of “bankrupt” and “insolvent” both come from the Merriam-Webster Dictionary.

demand to an area where water is available, or to shift to increasingly expensive sources, such as desalination or imports of goods produced in regions with adequate water supplies, the transfer of so-called virtual water.”⁴

In the context of Iran's unfolding water bankruptcy, this means that the country's water supplies may become so energy intensive and costly that economic constraints will force major changes to the country's grain cultivation and commodity import policies, its exportable oil and gas supplies, its choice of domestic energy sources, or most likely, all three. Water supplies do not “peak” in the same way that finite resources like oil or gas do, but ensuring them through measures such as deep aquifer pumping and desalination and transport of seawater is enormously energy intensive and would risk making irrigated wheat cultivation in many areas prohibitively expensive.

The future is far from determined and Iran possesses the capacity to restructure and exit water bankruptcy, but the country's political leaders and farmers face a stark set of trade-offs between food, water, and energy. Whether they can muster the will to overcome political and special interest inertia and move the country onto a more sustainable path before being forced to do so by a major crisis will be one of the country's biggest challenges of the next 25 years.

Iran's political and clerical leaders must decide whether they prefer to begin deep reforms now and spread the pain of change out over time, avoiding the worst looming problems, or continue with the status quo and set the country up for a violent impact in the future. To explain the situation with a physics analogy, consider the following: a driver traveling at 60 mph toward a concrete wall can dissipate the vehicle's energy gradually and protect passengers by braking over a distance of several hundred feet, or dissipate the energy suddenly and catastrophically by hitting the wall at full speed.

Why is Iran's Water Supply Under Such Stress?

Iran teeters on the brink of “water bankruptcy” in large part because the Iranian leadership's aspirations for food self-sufficiency are driving high agricultural water use.⁵ The Iranian government's focus on wheat self-sufficiency plays a major role in the country's water problems, as wheat is a staple of the Iranian diet and the country's dominant crop by tonnage produced. It is also frequently grown through irrigation, since much of Iran is too dry to reliably support rain-fed wheat cultivation and because yields of irrigated wheat fields are much higher. Irrigated wheat farms yield nearly three times as much grain per acre as rain-fed farms in Iran, according to the Food and Agriculture Organization of the United Nations (FAO).⁶ Despite these immediate private benefits, the social costs of irrigation are high—

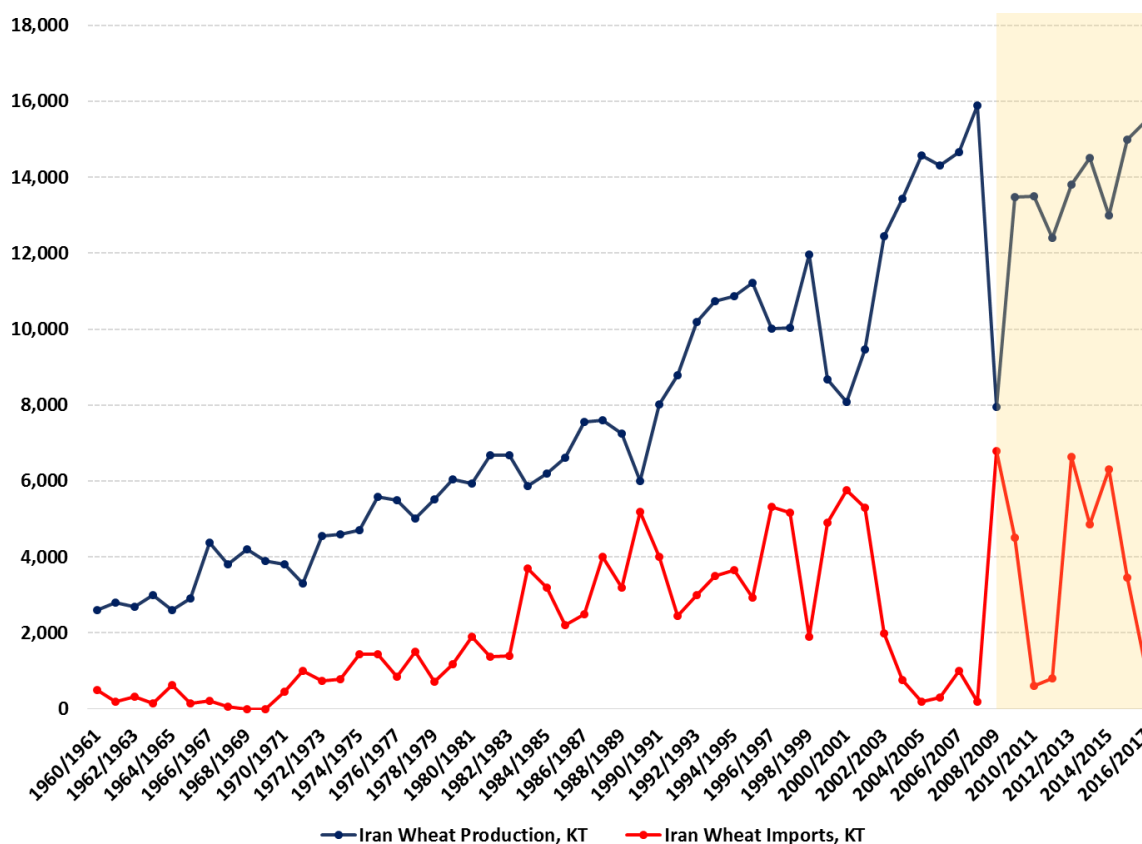
⁴ Peter H. Gleick and Meena Palaniappan, “Peak water limits to freshwater withdrawal and use,” *Proceedings of the National Academy of Sciences* 107(2010): 11155-11162.

⁵ Madani, Kouchak, and Mirchi, “Iran's Socio-economic Drought,” 997-1016.

⁶ “Irrigation in the Middle East region in figures – AQUASTAT Survey 2008: Iran,” http://www.fao.org/nr/water/aquastat/countries_regions/irn/irn-cp_eng.pdf (accessed 30 March 2017).

aquifers cannot recharge fast enough to offset pumping, meaning that irrigation boosts wheat output today, but risks leaving insufficient water for future generations.

Figure 1. Iran Continues to Seek Wheat Self-Sufficiency Despite Drought and Growing Strain on Aquifers



Source: U.S. Department of Agriculture.

Farm subsidy programs exacerbate Iran's water insecurity. Consider that in 2016, of the roughly 14 million tonnes of wheat grown by farmers in Iran, nearly 12 million (roughly 85%) were purchased by the government at guaranteed prices.⁷ Furthermore, the average purchase price came out to US\$340/ton—more than twice the average spot price during 2016 for No.2 soft red winter wheat from U.S. Gulf Coast export hubs and 87% more expensive than milling wheat exported from Russia's Port of Novorossiysk in 2016.⁸

⁷ "Gov't Wheat Purchases Surpass 11 Million Tons," *Financial Tribune*, September 28, 2016, <https://financialtribune.com/articles/economy-business-and-markets/50617/gov-t-wheat-purchases-surpass-11m-tons>.

⁸ Ibid. Price data obtained from Bloomberg.

The overuse of Iran's increasingly strained groundwater resources is unlikely to relent in the near future. Indeed, the country's leadership has made rising wheat production (much of which is irrigated with groundwater) a point of pride. For instance, in September 2016, President Hassan Rouhani noted that "We had a good year that led Iran to stop importing wheat. We are planning to export wheat in the coming months."⁹ The reported US Department of Agriculture numbers suggest that Rouhani's claims of Iranian wheat self-sufficiency are incorrect, as production for the 2016–17 crop year is estimated to be 15.5 million tonnes, versus estimated domestic consumption of 18.5 million tonnes, according to the USDA. Yet despite the numerical disparity, Rouhani's statement clearly reflects the Iranian government's strong support for continued, robust domestic wheat cultivation, even if doing so is not hydrologically sustainable.

Troubled External Relations and Complex Internal Politics Perpetuate Over-Cultivation of Wheat

Iran's farming sector is becoming increasingly groundwater dependent. Data from the FAO show that the area equipped for surface water irrigation in Iran declined by 15% between 1993 and 2007, while the area irrigated with groundwater increased by 39%. During that same time, Iranian wheat production rose by nearly 50%, which strongly suggests that increased use of groundwater for irrigation helped underpin the growth of domestic wheat output.

As the irrigated area increased, the number of private tube wells climbed at a nearly exponential rate, from 40,000 to 50,000 registered tube wells in the 1970s to 500,000 registered wells by 2006.¹⁰ And these reported numbers may undercount the total. Iranian researchers believe there are a vast number of unregistered wells—equal to as much as one-third of the total number of registered wells—implying that Iran could have as many as 665,000 tube wells: in other words, one for every 7.6 hectares of groundwater irrigated farmland in the country.¹¹

Iran currently shows no sign of backing off its policy of maximizing domestic wheat production, and the government may encourage farmers to push output even higher to maximize self-sufficiency, particularly if relations with the United States worsen during the Donald Trump presidency. Emphasizing robust grain production also can help placate powerful internal interests. Foremost among these are the bonyads—basically, religious foundations—that ostensibly focus on religious and charitable works, but also are deeply engaged in many aspects of the Iranian economy, including agriculture.

⁹ Parisa Hafezi, "Iran now self-sufficient in wheat, hopes to export soon: president," *Reuters*, September 22, 2016, <http://www.reuters.com/article/us-iran-wheat-sufficiency-idUSKCN1IS2OR>.

¹⁰ P. Karimi, A.S. Qureshib, R. Bahramlooc, and D. Moldena, "Reducing carbon emissions through improved irrigation and groundwater management: A case study from Iran," *Agricultural Water Management* 108 (2012): 52–60.

¹¹ Ibid. Wells per area ratio calculated based on 2007 vintage Food and Agriculture Organization of the United Nations (FAO) data for the irrigated agricultural land area in Iran.

For instance, Astan Quds Razavi reportedly owns 75% of the land in Iran's second-largest city, Mashhad, as well as "vast tracts" throughout other parts of the country.¹² While the precise role the foundations play in Iranian grain cultivation is not well documented, ownership of land strongly implies the ability to (1) collect rental payments on the land itself and/or (2) collect a portion of the crops produced, either in kind or as a portion of sales proceeds. Both of these potential revenue generation channels would strongly incentivize the farmers who are tenants on the land to maximize wheat production so as to have sufficient income to pay rents and still have a profit left over.

There are also more prosaic—but equally powerful—incentives at the level of the individual farmer that tie into the motivations described above. The advent of private tube wells confers a high degree of independence upon farmers who formerly often had to rely on communal water supplies from local *qanat* systems, which consist of underground canals constructed and managed by local communities and from which withdrawals were closely regulated in order to ensure that all members had access to water.¹³

Private tube wells, on the other hand, offer groundwater to farmers whenever and however they want it, up to the well's maximum production capacity. In turn, such dynamics often create a tragedy of the commons because aquifers are drawn down as farmers race to maximize their grain harvests, depleting a public resource in order to secure a private gain. Accordingly, many of Iran's core farming areas are suffering significant groundwater depletion rates, sometimes exceeding one meter per year.

Herein lies the dark side of private water well ownership in Iran. When water is available, farmers can reap the benefits of outsized yields in many years. But when water tables decline, rural people are left exceedingly vulnerable. Scholars' interviews with rural Iranian farmers suggest that drought and water supply problems can trigger a range of health and social problems—such as diet deterioration and delayed marriages—whose consequences reverberate for years.¹⁴ Data also suggest that for many poor farming families, rising irrigation costs imposed by drought can be sufficient to drive them off the land and into cities in search of work.¹⁵

¹² Andrew Higgins, "Inside Iran's Holy Money Machine," *The Wall Street Journal*, June 2, 2007, <http://www.wsj.com/news/articles/SB118072271215621679>. The Imam Reza Shrine is one of the largest mosques in the world.

¹³ Paul Ward English, "Qanats and Lifeworlds in Iranian Plateau Villages," *Yale Forestry & Environmental Studies Bulletin* 103(1998): 187-205. Available at: <https://environment.yale.edu/publication-series/documents/downloads/0-9/103english.pdf>.

¹⁴ Marzieh Keshavarza, Ezatollah Karamia, Frank Vanclay, "The social experience of drought in rural Iran," *Land Use Policy* 30 (2013): 120-129.

¹⁵ Marzieh Keshavarz, Hamideh Maleksaeidi, Ezatollah Karami, "Livelihood vulnerability to drought: A case of rural Iran," *International Journal of Disaster Risk Reduction* 21(2017): 223-230.

Embargo Risk Heavily Influences the Iranian Government's Decision-making

Embargo risk helps highlight what probabilities mean to a leader considering food security issues, as well as their attendant water and energy trade-offs. Leaders in a country like Iran, which has faced severe economic sanctions, may decide that allowing extensive mining of groundwater in the near term is acceptable if it yields the impression of food security and greater national self-sufficiency, even though it leaves a much more serious set of problems for future generations of political leaders.

Growing more grain domestically appears to be fundamentally motivated by several scarring experiences of the past 35 years. The first was the war with Iraq and growing hostility in relations with the United States in the wake of the 1979 Islamic revolution. The second factor stems from more recent sanctions, beginning with the Iran and Libya Sanctions Act of 1996 and culminating in the extreme enforcement of trade and financial restrictions by the Obama administration, even to the point of imposing sizeable financial penalties for small sales of medical equipment.¹⁶ As sanctions enforcement progressively tightened, Ayatollah Ali Khamenei began discussing the idea of a “resistance economy”—a theme he has maintained for the better part of five years.¹⁷

The resistance economy concept emphasizes self-sufficiency and isolation from global markets in order to reduce Iran's vulnerability to external pressures, such as those imposed by the United States and European Union embargoes related to the country's nuclear program. Ray Takeyh of the Council on Foreign Relations pointedly describes the current status of the “resistance economy” issue, noting “At its core, the question that divides Iran today is whether integration into the global economy endangers the revolution or ensures the survival of the state.”¹⁸ The ultimate solutions to Iran's water crisis will also depend in great measure upon the outcome of the ongoing resistance economy debate.

Taken together, the combination of the “resistance economy” ideology among top clerics, bonyad influence, subsidized energy and other inputs for farmers, high-level political support for wheat self-sufficiency, farmers' ability to control their own short-term productivity using private tube wells, and the agricultural sector's role as a core strategic employer of nearly one out of every five Iranian workers suggests that groundwater depletion will continue. Iran likely

¹⁶ See, for instance, “Brasseler USA Settles Potential Civil Liability for Alleged Violations of the Iranian Transactions Regulations,” Office of Foreign Assets Control, Department of the Treasury, October 19, 2012, https://www.treasury.gov/resource-center/sanctions/CivPen/Documents/20121019_brasseler.pdf. Brassler's sale of \$5,241-worth of medical equipment that was transshipped to Iran drew penalties of at least \$21,000.

¹⁷ Najmeh Bozorgmehr, “Iran develops ‘economy of resistance,’” *Financial Times*, September 10, 2012, <https://www.ft.com/content/27ec70a6-f911-11e1-8d92-00144feabdc0>; and Bozorgmehr Sharafedin and Babak Dehghanpisheh, “Iran's Khamenei criticizes government's economic record,” *Reuters*, March 20, 2017, <http://www.reuters.com/article/us-iran-khamenei-new-year-idUSKBN16R12U>.

¹⁸ Ray Takeyh, “Iran's ‘Resistance Economy’ Debate,” Expert Brief, Council on Foreign Relations, April 7, 2016, <http://www.cfr.org/iran/irans-resistance-economy-debate/p37748>.

will only reduce staple grain cultivation if the decision is forced by irresistible natural factors—first and foremost, continued drought, and second, aquifers becoming depleted to a point that industrial-scale water extraction is no longer feasible.

Energy and Environmental Consequences of Groundwater Becoming Unusable or Physically Inaccessible

Once aquifers are sufficiently depleted, water accessibility becomes directly proportional to the energy inputs a user can devote to the extraction, processing, and transport of water from one region to another. Ultimately, the only truly inexhaustible water source—at least in purely physical terms—is seawater desalination. Yet utilizing desalinated seawater would entail enormous energy expenditures (detailed below).

The second resource, groundwater, can be over pumped and cause well water yields to drop to a point that irrigated farming may cease to be feasible in an area due to the simple inability to produce sufficient water. This phenomenon already affects western portions of the Midwestern US Grain Belt that rely on water from the High Plains Aquifer to sustain crop production.¹⁹ Groundwater depletion has exerted even more profound effects in the state of Gujarat in Northern India, where villages atop a declining water table have seen cultivated areas decrease by as much as 17% during non-monsoon seasons.²⁰

Iranian farmers in key wheat-growing regions do not have access to monsoon rains, and a continued decline in groundwater availability that renders wells nonfunctional could have significantly more disruptive impacts than those suffered to date by drier parts of India. The writing is on the wall in key Iranian wheat-growing regions with respect to groundwater depletion. For instance, Zarindasht County, a highly productive area of Fars Province, Iran's single-largest wheat-producing area, saw groundwater levels decline by 3.4 meters during the 2003–2011 drought.²¹

Similarly, groundwater over pumping can trigger salinization as aquifers suffer intrusion of seawater or saline surface waters or as salinity increases due to communication with deeper, brackish groundwater. Irrigating with more saline waters increases the concentration of salts in the soil and can dramatically decrease grain yields. For instance, several studies suggest that under irrigation with highly saline water, wheat yields consistently decline by more than 20%—and sometimes much more—relative to crops

¹⁹ Michael Wines, "Wells Dry, Fertile Plains Turn to Dust," *The New York Times*, May 19, 2013, <http://www.nytimes.com/2013/05/20/us/high-plains-aquifer-dwindles-hurting-farmers.html>.

²⁰ Avinash Kishore, "When Wells Fail: Farmers' Response to Groundwater Depletion in India," CGIAR, June 10, 2014, <https://wle.cgiar.org/thrive/2014/06/10/when-wells-fail-farmers%E2%80%99-response-groundwater-depletion-india>.

²¹ Keshavarza, Karamia, and Vanclay, "The Social Experience of Drought in Rural Iran," 120-129.

irrigated with less saline water.²² The wheat in these studies was irrigated at maximum salt concentrations of or 9,600 to 10,400 mg/liter total dissolved solids (EC of 12.0 to 13.0 dS/m).²³ To put the salinity of this water in perspective, bear in mind that ranchers are generally advised to avoid watering livestock with sources containing 7,000 or more mg/l of total dissolved solids.²⁴ In some cases, chemical treatments can mitigate the impacts of certain types of salinity—particularly those caused by sodium ions—but such treatments are likely to be unaffordable to many lower-income farmers.²⁵

If the country maintained that grain self-sufficiency should be kept as high as possible as a matter of strategic policy, then the only large-scale sources of water would be either deep groundwater pumping or desalination of seawater, with the desalinated water transported to agricultural areas of inland Iran. Both approaches would be extremely energy intensive. To put in context the energy use and cost of supplying unconventional water to grain farms, consider desalinated water, which illuminates the extreme end of the food-energy-water nexus in Iran. If farmers in Central Iran grew 10% of the country's current wheat supply with desalinated water from the Persian Gulf, this author estimates that desalinating the requisite volume of water and moving it from sea level and over mountains into the Central Plateau would require roughly 1.9 BCF/d of gas (see Table 2).

This would be equivalent to approximately 10% of Iran's daily gas consumption in 2015. Another way to think about this level of gas use is what it could mean in terms of lost potential LNG exports if Iran chose to become a global gas exporter. A volume of 1.9 BCF/d equals approximately 13 million tonnes per year of LNG.²⁶

While Iran is not currently an LNG exporter, using LNG exports offers a way to measure the potential economic opportunity costs of using gas supplies to produce energy intensive water resources for low value-added agricultural activities such as bulk grain cultivation. At a conservative sale price of \$300/tonne, 13 million tonnes per year of LNG would be worth approximately \$3.9 billion in annual revenue. As such, the implied energy cost per tonne of wheat grown with desalinated water would be approximately \$2,500/tonne. In contrast,

²² See, for instance, M.A. Mojid, K.F.I. Murad, S.S. Tabriz, and G.C.L. Wyseure, "An advantageous level of irrigation water salinity for wheat cultivation," *Journal of the Bangladesh Agricultural University* 11(2013): 141–146, <http://ageconsearch.umn.edu/bitstream/209763/2/18225-65623-1-PB.pdf>.

²³ Clarence Chavez, "Electrical Conductivity or Salt Concentration," USDA, Undated presentation, https://prod.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs144p2_067096.pdf.

²⁴ Saqib Mukhtar, "Water Quality Guide for Livestock and Poultry," Texas Agricultural Extension Service, The Texas A&M University System, http://publications.tamu.edu/WATER/PUB_water_Water%20Quality%20Guide%20for%20Livestock%20and%20Poultry.pdf.

²⁵ Tony Provin and J.L. Pitt, "Managing Soil Salinity," Texas Agricultural Extension Service, Texas A&M University System, http://oaktrust.library.tamu.edu/bitstream/handle/1969.1/86985/pdf_1397.pdf.

²⁶ Liquefaction consumes roughly 9% of the total original gas volume, so LNG volumes are smaller than would be implied based on the starting volume of gas. See "Macroeconomic Impacts of LNG Exports from the United States," NERA Economic Consulting, December 2012, https://energy.gov/sites/prod/files/2013/04/f0/nera_lng_report.pdf.

the prompt cash price of US No. 2 soft red winter wheat at the Louisiana Gulf Coast, a proxy for global seaborne import prices, was \$177/tonne in early February 2017, implying a “social cost” of more than \$2,300/tonne for domestic wheat grown in Central Iran and irrigated with desalinated water transported from the Gulf coast.

Table 2. Potential Energy Requirements of Growing 10% of Current Iranian Wheat Production with Desalinated Seawater

Iran National Average		
Water Footprint per Tonne of Wheat	3,690	M ³
Wheat Grown	1,550,000	Tonnes
Implied Water Needs	5,719,500,000	M ³
De-Salination Phase		
Energy Use per M ³ of water produced	3.50	kWh
Electricity per M ³ of water produced		
Pumping Phase		
Line length	500	km
Pump stations	7	
Transmission Loss Factor	10%	
Annual Water Delivery Needs (Including transmission loss factor)	6,291,450,000	cubic meters
Lift Distance	1,500	meters
Specific Power Use to Move Water Over Mountains	0.0042	kWh/M/M ³
Energy Use for Horizontal Pumping	0.0002	kWh/M ³ /km
Implied Energy Use to Deliver Water	9.9	kWh/M ³
Implied Annual Energy Use	62,411,184,000	kWh
BTU/kWh	3412.14	
Natural Gas Equivalent (raw)	212,955,697	mcf
Natural Gas Equivalent (raw)	213	BCF
Natural Gas Equivalent (adjusted for power plant heat rate)	608	BCF
Natural Gas Equivalent (adjusted for powerline transmission losses)	694	BCF
Natural Gas Implied Demand, All In, BCF/D	1.9	BCF/d

Sources: UNESCO-IHE Advanced Water Institute; Kennedy/Jenks Consultants, National Water Research Institute; Renewable and Sustainable Energy Reviews; Journal of Environmental Management; and World Bank.²⁷

²⁷ M.M. Mekonnen and A.Y. Hoekstra, "A Global and High-Resolution Assessment of the Green, Blue and Grey Water Footprint of Wheat," UNESCO-IHE Advanced Water Institute, Value of Water Research Report Series No.42(2010), <http://doc.utwente.nl/76916/1/Report42-WaterFootprintWheat.pdf>; Nikolay Voutchkov, "Seawater Reverse Osmosis Design and Optimization," presentation at Advanced Membrane Technologies workshop, Stanford University, May 7, 2008, Kennedy/Jenks Consultants, National Water Research Institute, <http://web.stanford.edu/group/ees/rows/presentations/Voutchkov.pdf>; A.K. Plappally and J.H. Lienhard V, "Energy requirements for water production, treatment, end use, reclamation, and disposal," *Renewable and Sustainable Energy Reviews* 16(2012): 4818–48, <http://dx.doi.org/10.1016/j.rser.2012.05.022>; Arani Kajenthira, A. Siddiqi, and L.D. Anadon, "A new case for promoting wastewater reuse in Saudi Arabia: Bringing energy into the water equation," *Journal of Environmental Management* 102(2012) 184-192; World Bank, Power Line Transmission Loss Data, <http://data.worldbank.org/indicator/EG.ELC.LOSS.ZS>.

Iran is Already Building Infrastructure to Provide Desalinated Water Supplies to Inland Areas

Toossab Consulting Engineers Company is currently overseeing the construction of a pipeline from a desalination facility in Bandar Abbas, along Iran's southeast Persian Gulf coast, to an iron ore mine nearly 300 km inland.²⁸ The project is slated to move 110 million m³ of water per year from sea level to the Golgohar iron ore mine, located at an altitude of 1,700 meters, and eventually on to a copper mine located at 2,700 meters altitude, then carry water to steel plants in Yazd Province.²⁹

The Golgohar project's first phase alone is estimated to cost more than US\$1 billion, and to credibly supply agricultural operations in Iran's interior, projects would need to be built that could supply dozens of times more water as the Golgohar line will be able to.³⁰ The total construction costs of an "unconventional" water supply system aimed at counteracting groundwater and surface water supply deficits would be massive. South Korea's Doosan Heavy Industries & Construction recently secured a \$183 million deal to build a desalination plant in Bandar Abbas capable of producing approximately 200,000 m³ of freshwater per day.³¹ Extrapolating the implied capacity cost of \$2.50/m³/year, supplying enough water to grow just 1% of Iran's current domestic wheat production would mean investing more than \$1.4 billion in desalination plants alone. And this estimate is only for the capital costs of the plants: it does not include the substantial operating costs, such as energy inputs, required to run the desalination plants.

Energy expenditures to move the water would also be commensurately large, since the main energy expenditure comes from lifting the water onto the high central plateau—a physical challenge imposed by gravity that cannot be overcome by economies of scale. Iran has the potential energy supply base to construct and operate infrastructure to sustain industrial-scale agriculture with desalinated seawater, but the opportunity costs in terms of natural gas use and foregone export revenues would be enormous.

As the country's leaders dip their toes into the desalination and deep groundwater pool and consider whether to expend capital and energy to fight the country's harsh climate, the fundamental trade-offs inherent in the food-water-energy nexus will be inescapable. Accordingly, the fastest and lowest-cost (and thus most likely) response when the country's

²⁸ "Water transmission pipe line from the Persian Gulf to the South East of the Country's Mining Industries," Toossab Consulting Engineers Company, <http://www.toossab.net/en/projects/detail/Water-transmission-pipe-line-from-the-Persian-Gulf-to-the-South-East-of-the-Country--39-s-Mining-Industries/150/view/> (accessed February 24, 2017).

²⁹ Ibid.

³⁰ "WASCO invites firms for USD1 bln scheme to build steel water pipeline," August 14, 2013, http://steelmillssoftheworld.com/news/newsdisplay_cntry.asp?sln=32487.

³¹ Lee Hyo-sik, "Doosan Heavy wins desalinization plant deal in Iran," *The Korea Times*, June 27, 2016, http://www.koreatimes.co.kr/www/news/biz/2016/06/123_207980.html.

water crisis begins to impact wheat and grain production is that Iranian food suppliers will seek to import wheat.

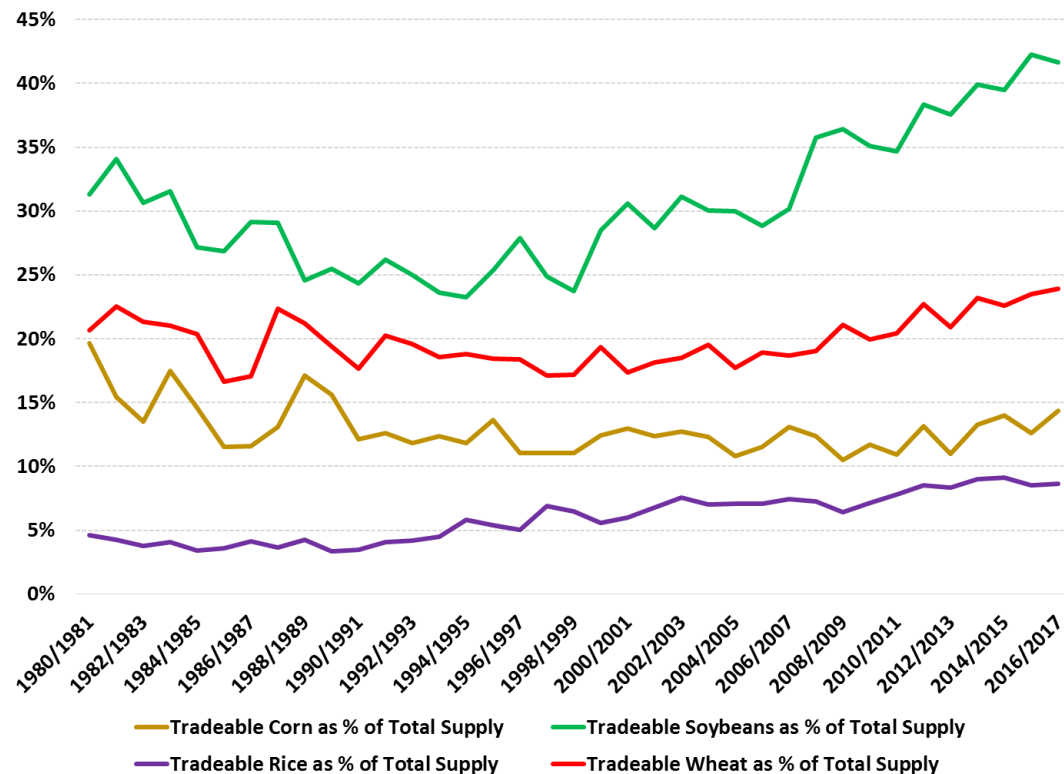
Wheat Imports Likely More Secure Than Iranian Leadership May Realize

The 1980 US grain embargo against the Soviet Union ultimately failed due to (1) opposition from US farmers, (2) the existence of alternative suppliers who stepped into the breach and sold grain to the USSR, and (3) improvements in the Soviet grain harvest in 1980 and the USSR's ability to tap into its grain reserves to help cover initial supply shortfalls.³² Similarly, a grain embargo would be difficult to enforce at present for both tactical and strategic reasons.

On the tactical level, the lifting of many trade restrictions on Iran after the 2014 nuclear deal and subsequent resumption of long-dormant commercial relationships will make many countries reluctant to cooperate with a US-led embargo. The growing international unpopularity of the Trump administration may further reduce various countries' propensity to cooperate with the United States in economically pressuring Iran. In addition, food-focused sanctions would likely be perceived as an attempt to starve Iran's population, and would likely be viewed as excessive and perhaps even outright illegitimate by much of the world. Lack of international consensus would increase the probability that (A) countries not aligned with the United States would continue shipping grain to Iran and (B) the United States would find itself diplomatically isolated on the issue. Meanwhile, on the strategic level, significant evolutions in the global grain markets make an embargo much tougher to enforce—particularly for wheat—than was the case in 1980.

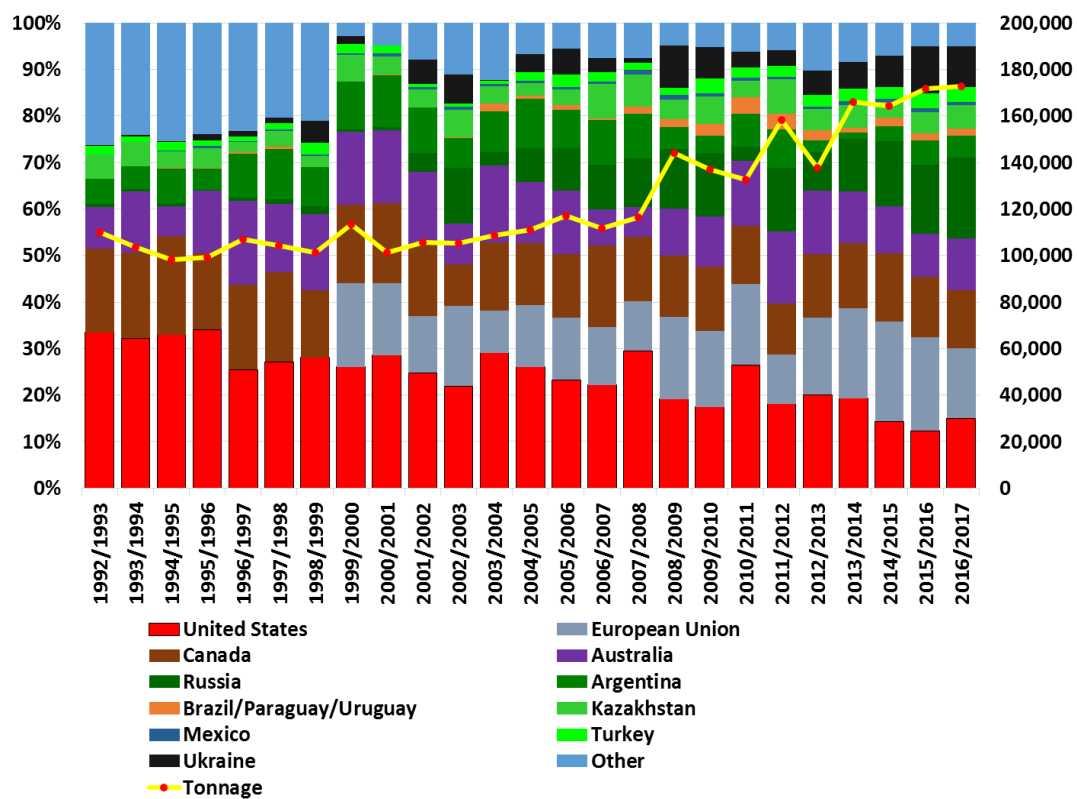
The “tradability” of a grain—in other words, its availability on the global export market—offers a useful metric for assessing how feasible it is for a country to procure needed supplies. In the latest crop year, USDA data show that nearly one out of every four tons of wheat produced globally enters the export market (Figure 3). This suggests that, barring a major supply disruption such as simultaneous crop failures in multiple, major producing countries, supplies will be economically accessible to a country like Iran that can use oil sales to generate hard currency.

³² Robert Paarlberg, “Lessons of the Grain Embargo,” *Foreign Affairs*, Fall 1980, <https://www.foreignaffairs.com/articles/united-states/1980-09-01/lessons-grain-embargo>, p. 146, 149-153, 157.

Figure 3. Tradeable Proportion of Key Staple Grains as a Percentage of Total Global Supply

Source: USDA; Baker Institute Center for Energy Studies.

Wheat is not only tradable—supplies also emanate from a diverse range of producers, including many who are either not aligned with Washington's foreign policy goals or, in the case of Russia, stand actively opposed to US foreign policy in key areas, including Iran. Eleven core exporters now account for 95% of wheat volumes traded internationally across the globe. In a development that should alleviate the concerns of countries such as Iran who fear that the United States might impose sanctions on grain exports, the US share of global wheat export supply has declined from nearly 34% in 1993–94 to an average of approximately 5% over the last five crop years (Figure 4).

Figure 4. The Global Wheat Export Market is Increasingly Diverse

Note: Left axis = percent of total export market; right axis = total global wheat tonnage exported.
 Source: USDA; authors' calculations.

The diverse global wheat exporter base and the fact that an increasing proportion of export supplies comes from countries whose foreign policies typically diverge sharply from Washington's strongly suggest that a grain embargo against Iran would be extremely difficult—if not practically impossible—to enforce on a sustained basis. Thus, Iranian factions who might use the specter of potential US sanctions to justify sacrificing domestic water resources to pursue wheat supply self-sufficiency should note the following: the global wheat export market share of countries that are unlikely to align with potential US attempts to restrict trade with Iran (or other Gulf countries, for that matter) has risen from 13% in the 1992 crop year to more than 40% in the 2016 crop year.³³

³³ For the purposes of this analysis, the “non-aligned” wheat exporter countries are: Argentina, Brazil, Kazakhstan, Paraguay, Russia, Turkey, Ukraine, and Uruguay. Other suppliers doubtless exist, but these are drawn from our sample set of 12 countries and one regional bloc (European Union) that now account for 95% of global wheat export tonnage, according to the USDA.

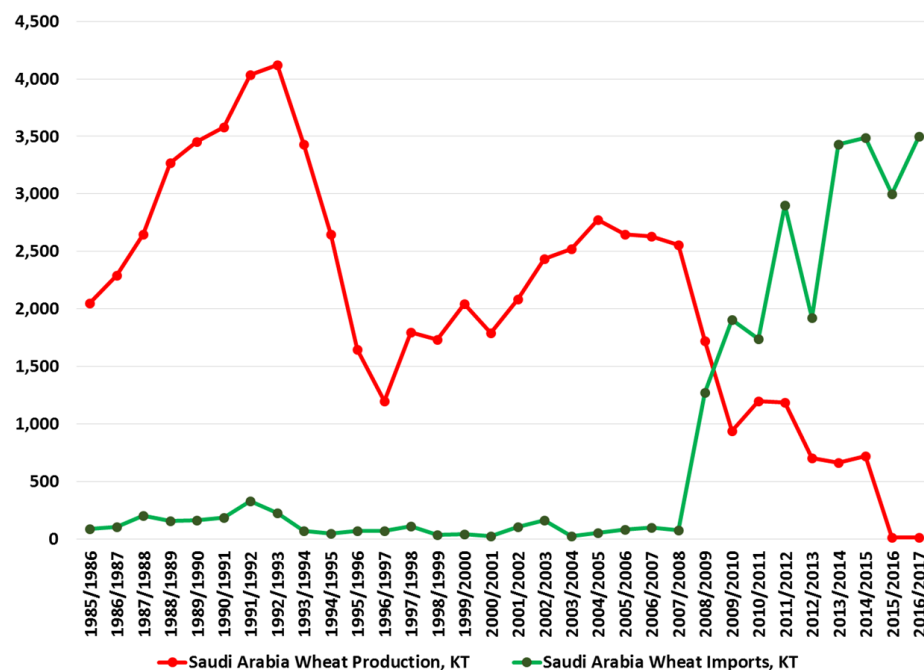
Suggested Policy Responses

Possible Policy Response 1: Reduce Domestic Grain Production and Import Supplies Instead

To the Saudi government's credit, it has recognized the hydrological unsustainability and economic irrationality of its own attempt to make the desert bloom and has dramatically reduced domestic grain cultivation. The kingdom's policy shift has reduced the area of land used for cereal cultivation back to levels not seen for more than 50 years and helps significantly reduce agricultural groundwater use.

Saudi Arabia's grain cultivation cutback is particularly apparent for wheat. In the 2015–16 agricultural market year, the kingdom finally ended its three-decade domestic wheat production and purchase program and became fully dependent on imports to supply its wheat needs.³⁴ The Saudi government began to dial back domestic wheat procurement in the 2007 market year per decree #335, which stipulated that each successive market year would see the Saudi Grain Silos and Flour Mills Organization (GSFMO) reduce registered farmers' wheat production quotas by 12.5% in order to eliminate domestic sourcing by the 2015 market year.³⁵ As a result, the kingdom is now 100% dependent on the global market for its wheat supply (Figure 5).

Figure 5. Saudi Arabia Abandons Wheat Cultivation and Goes Completely Import Dependent



Source: USDA.

³⁴ "Saudi Arabia ends domestic wheat production program," *World Grain News*, March 18, 2016, http://www.worldgrain.com/articles/news_home/World_Grain_News/2016/03/Saudi_Arabia_ends_domestic_whe.aspx?ID=%7B50E0E390-7C3F-46A6-B832-54FA58F140B2%7D&cck=1.

³⁵ Ibid.

Iran could follow a similar path by reducing—or completely eliminating—the current subsidized domestic wheat purchase program and replacing costly, water-intensive domestic supplies with imports. To be sure, reducing domestic grain cultivation to preserve Iran's depleting aquifers would be a politically complicated move, because agricultural activities employ so much of the country's workforce. While agriculture's share of total employment in Saudi Arabia has fallen from just under 8% in 1990 to approximately 5% in 2013, roughly 18% of Iran's workforce remains employed in the agricultural sector, according to World Bank data. Yet a subsidy reduction and move toward greater use of the global market would likely be among the most technically straightforward policies to implement and could rapidly begin reducing agricultural water use.

Potential Policy Response Number 2: Invest in More Efficient Irrigation Systems

The data are somewhat aged, but FAO Aquastat figures show that as of 2003, only about 3% of Iran's irrigated acreage used sprinklers, while 5% used drip irrigation systems.³⁶ Low penetration of advanced irrigation techniques suggests that, in theory, the country could leverage this space for improvement by investing in better irrigation practices to conserve water while still preserving large-scale farming activity. In practice, there is likely much less “headroom” for infrastructure-based water efficiency improvements than the numbers suggest.

The average irrigated farm in Iran is 2.9 ha in size, which suggests a prevalence of smallholders who lack sufficient capital to spend the US\$1,700 to \$2,500 per ha that sprinkler and drip systems respectively cost.³⁷ To put the capital investment numbers for advanced irrigation in perspective, the average rural Iranian household income in 2011 was approximately \$7,100.³⁸ Thus, putting an average Iranian farm plot on sprinklers could cost more than 70% of what the typical rural household brings in annually. The cost could be financed and spread out over time. But even then, payments would still constitute an unwelcome burden for many farming families that they would likely try to avoid unless incentivized by government subsidies or legal compulsion.

Potential Policy Response Number 3: Put a Real Price on Irrigation Water

Charging for water can dramatically reshape consumer behavior and promote efficiency. Iranian policymakers have significant latitude in this area because farmers are currently not charged any independent price for pumping groundwater for irrigation.³⁹ Rather, they only pay the capital and operational costs of water wells used to extract the resource. This results in an artificially low price for water because the diesel fuel and electricity used to power groundwater extraction in Iran are themselves significantly subsidized. Electricity prices are particularly low, with academic research finding that Iranian farmers bear as little as 5% of the

³⁶ See http://www.fao.org/nr/water/aquastat/countries_regions/IRN/index.stm.

³⁷ Ibid.

³⁸ See <https://www.amar.org.ir/english/Statistics-by-Topic/Household-Expenditure-and-Income#2220529-time-series>.

³⁹ Alireza Nikouei and Frank Ward, “Pricing irrigation water for drought adaptation in Iran,” *Journal of Hydrology* 503 (2013): 29-46. <http://dx.doi.org/10.1016/j.jhydrol.2013.08.025>.

total cost of electricity used by their wells.⁴⁰ The result is that water wells are fundamentally underpriced, which tends to discourage investment in more efficient irrigation infrastructure and practices, even ignoring the unpriced “scarcity value” of the water.

Water currently cannot legally be sold in Iran because the end use must match what the government has permitted for well water extractions.⁴¹ Furthermore, under current Iranian law, surface and groundwater are both considered public property.⁴² Yet this has not impeded the emergence of informal local markets where farmers who have water left over after meeting their own needs sell water or rent wells to neighbors who are short on water. While farmers cannot own the water itself, they can own water wells and maintain the right to extract the water as private property, and Iranian authorities rarely meter water withdrawals from private wells.⁴³ Without significant oversight and enforcement of water extraction and end user status, farmers can leverage their access to water sources and production infrastructure to become informal water marketers. However, the ability to purchase or sell water over long distances is beyond the capability of small farmers.

Despite water marketing being technically illegal, the practice appears widespread in many areas of the country. Indeed, the Iran Water and Power Resources Management Company estimated in March 2015 that in some cases, farmers were spending as much as 20% to 50% of their income on purchasing water in local spot markets (yet that probably covers “marginal” purchases, with “base use of water from their own wells” unpriced).⁴⁴

This suggests that the political reaction if the government began imposing formal charges on groundwater pumped for irrigation might actually be fairly muted. Field research suggests that private water sellers already often charge desperate customers very high rates (but fees would be charged to all farmers using water, not just those who lack sufficient water).⁴⁵ In fact, bringing water markets into the open and increasing transparency and information availability could incentivize water conservation while simultaneously increasing the amount of water available for sale, thus reducing the financial burdens

⁴⁰ Tinoush Jamali Jaghdani and Bernhard Brümmer, “Political Economy of Energy Subsidy–Groundwater Depletion

Nexus in Iran: the Role of Irrigation Water,” Tropentag, Conference on International Research on Food Security, Natural Resource Management and Rural Development, September 16-18, 2015, Berlin, Germany, http://www.tropentag.de/2015/abstracts/links/Jamali_Jaghdani_F3a4UA9A.pdf.

⁴¹ Tinoush Jamali Jaghdani, “Demand for Irrigation Water from Depleting Groundwater Resources: An Econometric Approach,” Ph.D. dissertation, Georg-August University Göttingen, Germany, December 2011. https://ediss.uni-goettingen.de/bitstream/handle/11858/00-1735-0000-000D-EF51-7/jamali_jaghdani.pdf?sequence=1.

⁴² “Law on Fair Distribution of Water,” UN FAO, Official Journal, No. 11112, 22 April 1983. <http://www.fao.org/faolex/results/details/en/?details=LEX-FAOC159738> (accessed 22 February 2017).

⁴³ Nikouei and Ward, “Pricing irrigation water for drought adaptation in Iran,” 29-46.

⁴⁴ “Water Trade in Informal Markets,” *Financial Tribune*, March 17, 2015, <https://financialtribune.com/articles/economy-domestic-economy/13370/water-trade-in-informal-markets>.

⁴⁵ Jaghdani, “Demand for Irrigation Water from Depleting Groundwater Resources.”

suffered by water-poor farmers who must presently source some of their water from the informal markets.

Ultimately, the most practical method for increasing the “cost” of water will come through further reforms to diesel fuel and electricity prices, since these are the predominant energy sources utilized for groundwater extraction. Using these energy inputs as the primary vehicle for inducing water conservation also has the added benefit of allowing the government to preferentially price electricity, which could reduce emissions associated with diesel fuel use and also free up diesel supplies for sale into high-value export markets.

Conclusion

During the next 12 to 24 months, Iran's government will face tough choices as it confronts the countervailing realities of the country's water insolvency and pursuit of wheat self-sufficiency. Decisions it makes during this time will influence the country's energy, food, and water balance for years to come.

If drought continues in wheat-growing areas, Iran will likely boost imports to compensate for supply shortfalls. As shown in Figure 1, the country has proved willing to enter the global wheat market to procure supplies during several years over the past decade when domestic harvests fell short. The difference is that if harvest shortfalls come from declines in groundwater availability—Iranian farmers' most dependable supplies to date—the country would come into the wheat import market in a much more sustained fashion. This could entail Iranian buyers procuring significant volumes, perhaps exceeding 7 to 8 million tonnes per year, or at least twice what Saudi Arabia imported during the 2016–17 market year.

Yet the country's strategic policy orientation may wind up being less market oriented. Initial signs suggest that Tehran prefers to expend energy resources to try and maintain water supplies, rather than demand agricultural reforms. Alireza Daemi, the energy ministry's deputy for planning and economic affairs, noted in February 2017 that “We cannot use our natural water resources (surface and groundwater) to meet the demand in rural and crisis-hit areas...Our plan is to tap recycled wastewater and purified saltwater, among others, to meet the demand.”⁴⁶

Given the energy intensity and financial cost of building and operating industrial-scale desalination plants and water transport infrastructure, it is likely that the government will use desalinated water to ensure cities' drinking water supply, “buying political breathing room” while it decides how to handle the larger structural problems posed by the fundamental economic and hydrological unsustainability of Iran's present agricultural model.

⁴⁶ “Iran's Next Budget Focuses on Railroad, Environment, Water,” *Financial Tribune*, February 11, 2017, <https://financialtribune.com/articles/domestic-economy/59310/irans-next-budget-focuses-on-railroad-environment-water>.

Iran's ultimate decisions on whether to devote a significant portion of domestic gas supplies to powering desalination and long-distance water transfer infrastructure will substantially influence the country's domestic energy use profile, its potential for near- and medium-term exports of natural gas, its economic growth potential, and global wheat prices.

On a strategic level, the government's handling of the unavoidable stress points in the food-energy-water nexus will be a politically risky exercise. The most fundamental issues at stake are agricultural sector reform and, relatedly, energy input pricing and subsidy reform. Both of these spheres are domestic issues for which the government cannot readily use foreign entities as scapegoats if problems arise. As hardline clerics who advocate developing a full-fledged resistance economy clash with moderates seeking greater reintegration of Iran's economy into the global system, it is likely that the Iranian government will take an approach of cautious incrementalism. In practice, this will likely mean periodic wheat imports to fill supply shortfalls, more development of energy-intensive marginal water sources such as desalination and deep groundwater, delays in true reforms to agricultural water use practices, and ultimately, significant additional water-driven economic, demographic, and political dislocations within the next five years.